NATIONAL BUREAU OF STANDARDS REPORT

4449

Analysis of Mercury Lamps and Filter Combinations
for Use as Aviation-Green Lights

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS
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THE NATIONAL BUREAU OF STANDARDS

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1. PURPOSE OF ANALYSIS

The purpose of this analysis is to compute the luminous transmittance and chromaticity coordinates of present aviation-green filters (designed for use with incandescent lamps) when they are used in combination with currently available mercury lamps. Should these combinations fail to meet either the present or proposed aviation-green light specification, suitable filters would then be designed.

2. MERCURY LAMPS

The energy radiated in the visible region by mercury lamps consists of spectral lines and a continuum. The spectral-emittance data for mercury lamps used in this analysis were obtained from General Electric Company's brochure LS-103, June 1955. The performance of the following lamp types was analyzed: H250-A5, BH6, H400-E1 and H1000-A15. The relative spectral-emittance data for these lamps are shown in figure 1.

The luminous efficiency index of each of these lamps and of an incandescent lamp operated at 2854°K, listed in table I, indicates that the mercury lamps are relatively efficient in the production of visible radiant energy. The luminous-efficiency index of a lamp is defined as:

$$100 \frac{\int_{380}^{760} P_\lambda \bar{y}_\lambda \, d\lambda}{\int_{380}^{760} P_\lambda \, d\lambda}$$

where P_λ is the spectral radiant flux and $\bar{y}_\lambda$ is the CIE relative luminous-efficiency function.

Also listed in table I are the chromaticities of mercury lamps, H250-A5 and BH6 and of an incandescent lamp operating at 2854°K. The chromaticity coordinates of these lamps are plotted

on figure 2. Detailed analysis of the H250-A5 lamp was undertaken because its spectral distribution closely resembles that for H400-E1 and H1000-A15. Detailed analysis of the BH6 lamp was undertaken because this lamp differs from the others by having a higher spectral continuum.

Table I

Chromaticity, Luminous-Efficiency Index, and Efficiency of Mercury and Incandescent Lamps

Lamp Type	Chromaticity Coordinates x	y	z	Luminous-Efficiency Index	Efficiency (Rated Lumens per Watt)
H250-A5	0.318	0.379	0.303	54	44
BH6	.277	.330	.393	40	65
H400-E1	--	--	--	55	50
H1000-A15	--	--	--	55	52
Incandescent	.448	.408	.144	25	20

2.1 Performance of Mercury Lamps with Conventional Aviation-Green Filters.

In computing the performance of the lamps with aviation-green filters, spectral transmittance data, T_λ, for the transmittance standard, WF590, were used. Luminous transmittance, T, of this filter was computed for an incandescent tungsten lamp operated at 2854°K as well as for the mercury lamps. Chromaticity coordinates, x, y, and z, and luminous transmittance were computed for the H250-A5 and BH6 mercury lamps and the incandescent lamp. These computed results are listed in table II. The chromaticity coordinates are plotted on figure 2.

Table II

Luminous Transmittance and Chromaticity Coordinates of Lamp and Aviation-Green Filter Combinations

Lamp Type	Chromaticity Coordinates x	y	z	T (percent)
H250-A5	0.232	0.276	0.492	22
BH6	.192	.249	.559	27
H400-E1	--	--	--	21
H1000-A15	--	--	--	22
Incandescent	.205	.400	.395	20

The colors of the combination of the aviation-green filter and the mercury lamps are obviously too blue for use as aviation-green lights. The mercury lamps provide little increase in luminous transmittance over the incandescent lamp.

3. DESIGN OF FILTERS FOR MERCURY LAMPS TO YIELD AVIATION-GREEN LIGHT

If the radiant energy emitted by the mercury lamp in the visible region of the spectrum were composed entirely of spectral lines 404.7, 435.8, 546.1, and 578.0 mμ, the color of any mercury lamp-filter combination would lie within a chromaticity region defined by these spectral lines. This chromaticity region is shown by dashes on figure 2. If we wish to obtain a color that will lie in the aviation-green chromaticity region, a filter is required that will almost completely absorb the energy of line 578.0 mμ and will partially absorb the energy of lines 404.7 and 435.8 mμ.

As no single filter known can satisfy these requirements, two-component filter combinations of Didymium and Noviol filters were tried. Didymium filters have an absorption band in the region of 578 mμ and Noviol filters absorb energy in the blue and violet regions of the spectrum.

The design data for the two combinations that show promise of usefulness are listed in table III. The thickness of each filter component is designed on the basis of spectral data published in Glass Color Filters, Corning, 1948, for stock thickness t_0.

Table III

Filter Design Data

Filter Designation	Corning Ident. No.	Relative Thickness	Name
A	1-63	0.4 t_0	Didymium
	3-72	0.5 t_0	Noviol B
B	1-63	1.0 t_0	Didymium
	3-73	1.0 t_0	Noviol A

Figure 3 shows the computed spectral transmittance of the components and the combination of designed filter A. Figure 4 shows the computed spectral transmittance of the components and

the combination of designed filter B. The location of each mercury spectral line is indicated by an arrow on figures 3 and 4.

The chromaticity coordinates and luminous transmittance of filters A and B in combination with lamps H250-A5 and BH6 were computed. The results of these computations are listed in table IV. The chromaticity coordinates are plotted on figure 2.

Table IV

Chromaticity Coordinates and Luminous Transmittance of Mercury Lamps and Designed Filter Combinations

Filter Designation	Lamp Type	Chromaticity Coordinates x	y	z	Luminous Transmittance (percent)
A	H250-A5	0.356	0.587	0.057	60
A	BH6	.313	.522	.165	66
B	H250-A5	.273	.425	.302	48
B	BH6	.267	.376	.358	56

4. DISCUSSION

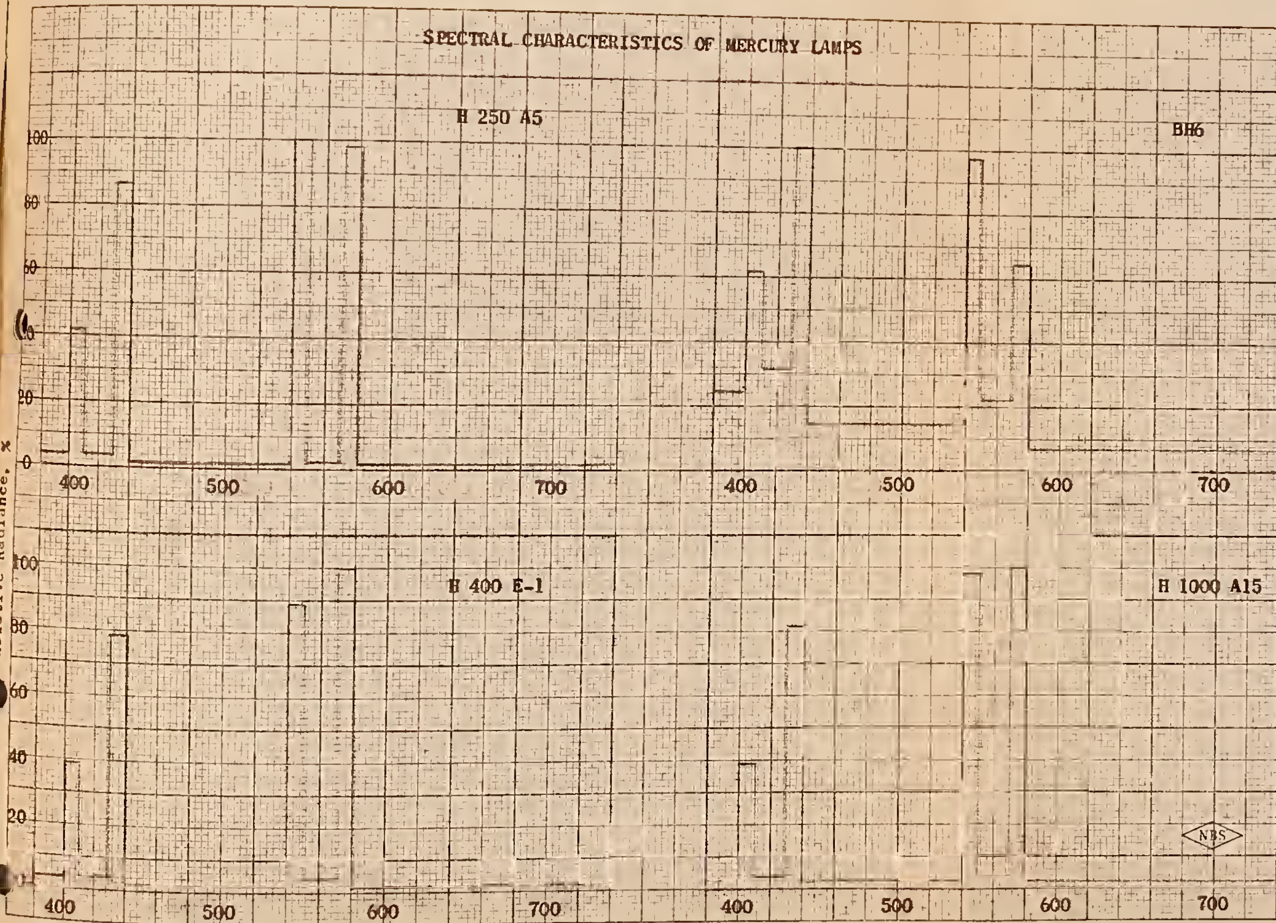
The chromaticity coordinates for mercury lights show that the color of each light lies on the green side of the Planckian Locus near 6000°K. The chromaticity of the mercury lamps in combination with the present aviation-green filter indicates that the resulting color is too blue for aviation green. The H250-A5 lamp in combination with designed filter B and the BH6 lamp in combination with designed filter A satisfy the proposed aviation green limits. Designed filter A shifts the color of mercury lamps toward yellow-green, while designed filter B shifts the color of the mercury lamp toward green.

The mercury lines plotted as points on the spectrum locus of figure 2 serve to define approximately the chromaticity region within which chromaticities of mercury lamp-filter combinations will lie. The BH6 lamp in combination with the present aviation-green filter falls just outside of this region because of the high spectral continuum in the spectral region of 490 mμ.

The chromaticity region defined by the mercury lines indicates that use of mercury lamps is theoretically possible for lunar white,

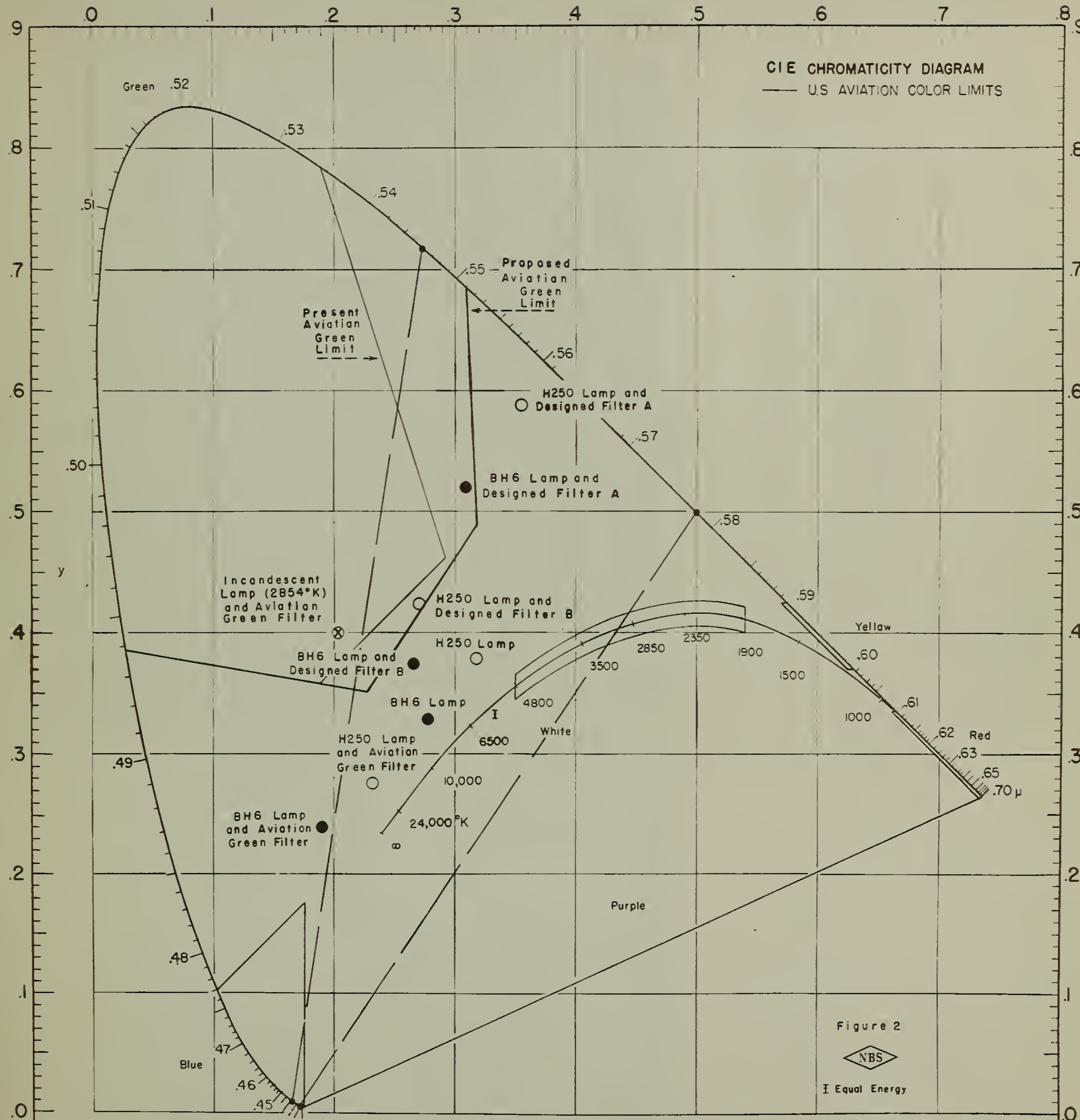
aviation blue, and aviation green. For lunar white, line 546 mμ needs to be eliminated. For aviation blue, lines 546 mμ and 578 mμ need to be greatly reduced. For aviation green, line 578 mμ needs to be eliminated, and lines 405 mμ and 436 mμ reduced.

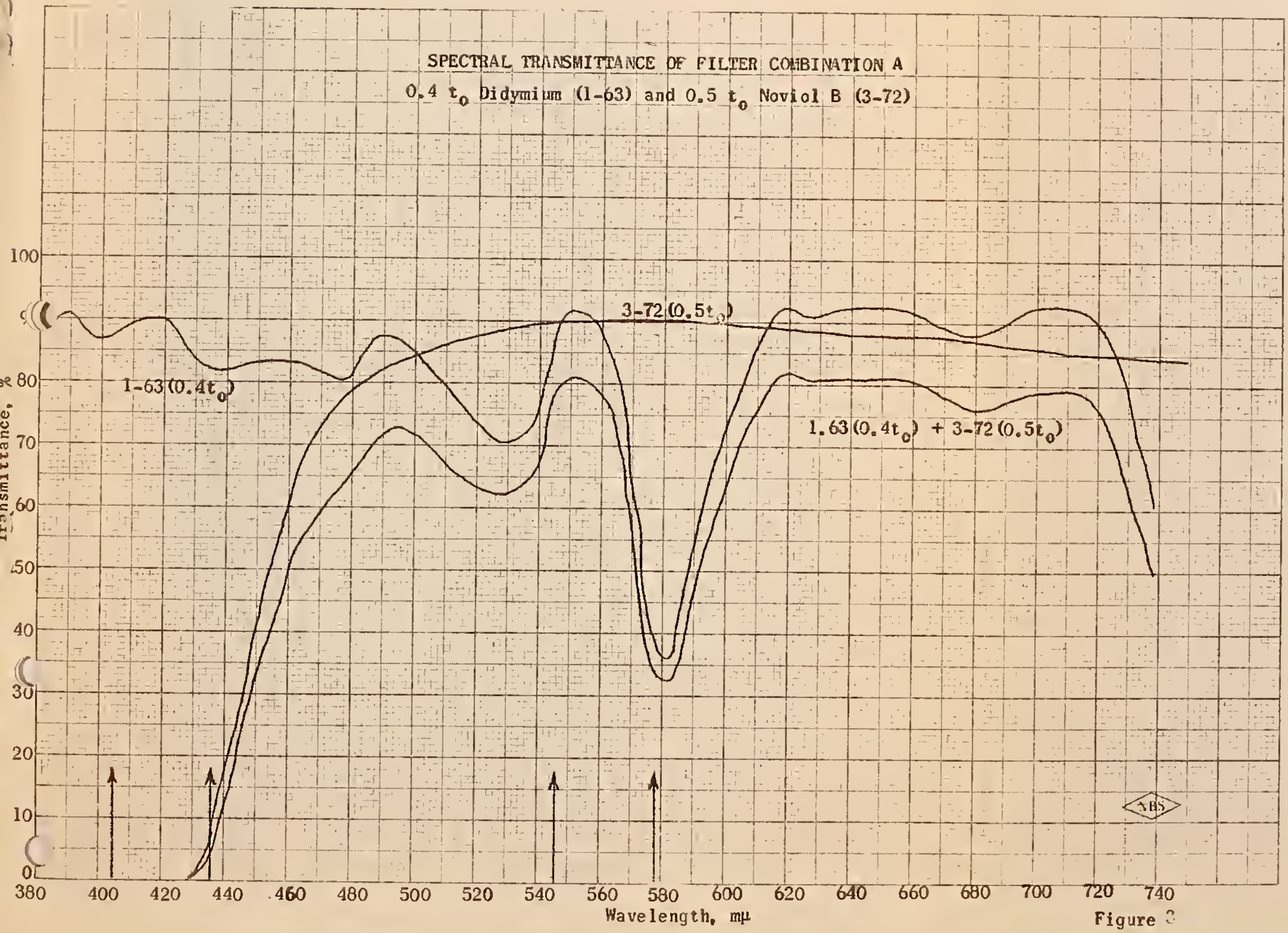
In the use of mercury lamps, precaution should be taken to dissipate the heat produced by the ultraviolet radiation that will be absorbed by the filter. The absorbed radiation might heat the filter to the cracking point. Incandescent lamps emit very little ultraviolet radiant energy but have much infrared. The filters in use with incandescent lamps generally transmit the infrared so no special precautions need be taken.



SPECTRAL CHARACTERISTICS OF MERCURY LAMPS
H 250 A5
BH6
H 400 E-1
H 1000 A15
Relative Radiance, %
0
20
40
60
80
100
400
500
600
700
Wavelength (mμ)
NBS

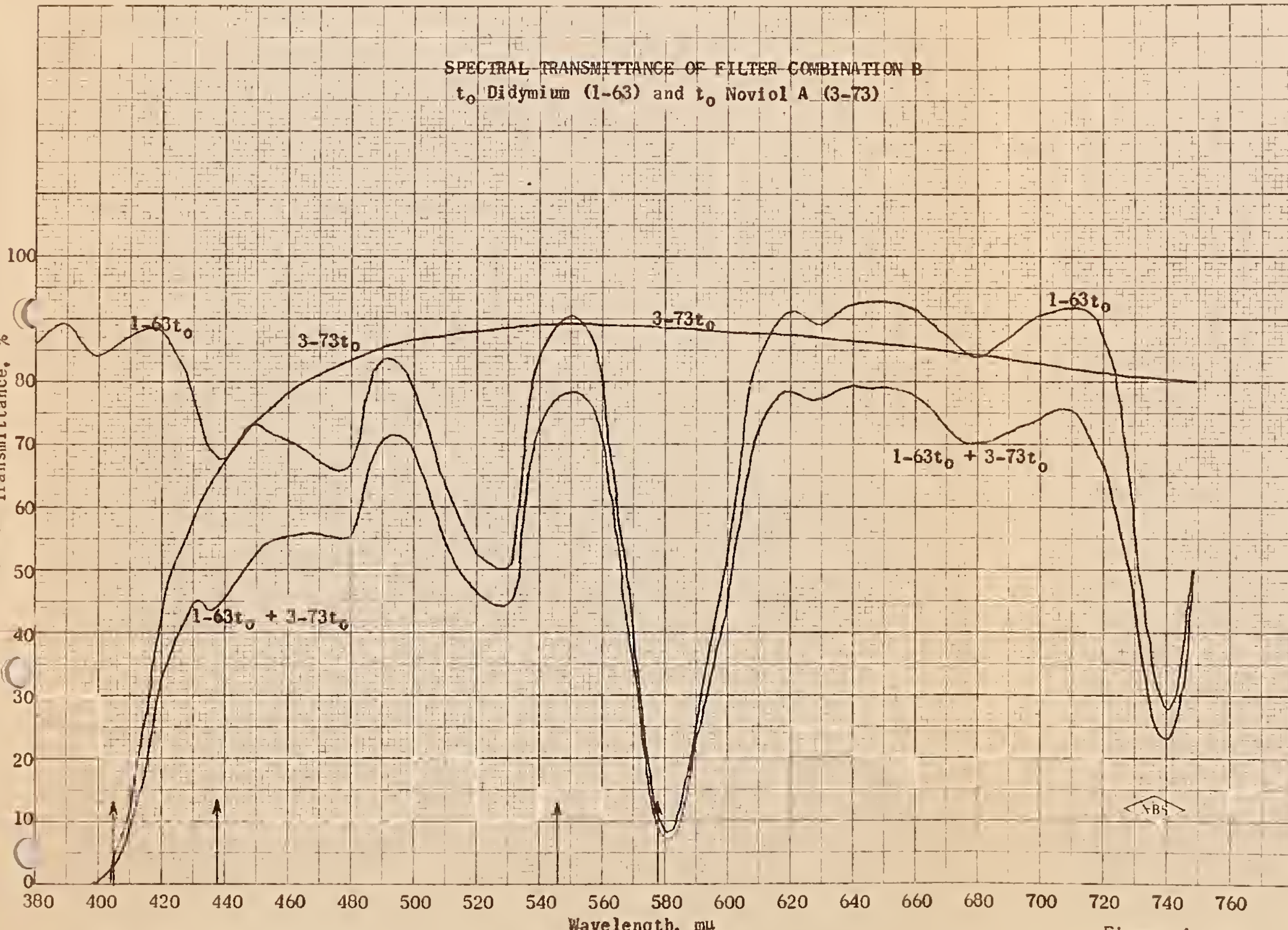
Figure I


CIE CHROMATICITY DIAGRAM
U.S. AVIATION COLOR LIMITS
Green
Blue
Yellow
Red
Purple
White
Proposed Aviation Green Limit
Present Aviation Green Limit
H250 Lamp and Designed Filter A
BH6 Lamp and Designed Filter A
Incandescent Lamp (2854°K) and Aviation Green Filter
H250 Lamp and Designed Filter B
H250 Lamp
BH6 Lamp and Designed Filter B
BH6 Lamp
H250 Lamp and Aviation Green Filter
BH6 Lamp and Aviation Green Filter
.42.38 μ
.45
.46
.47
.48
.49
.50
.51
.52
.53
.54
.55
.56
.57
.58
.59
.60
.61
.62
.63
.65
.70 μ
1000
1500
1900
2350
2850
3500
4800
6500
10,000
24,000 °K
∞
x
y
Figure 2
NBS
I Equal Energy



SPECTRAL TRANSMITTANCE OF FILTER COMBINATION A
0.4 t_0 Didymium (1-63) and 0.5 t_0 Noviol B (3-72)
3-72 (0.5t_0)
1-63 (0.4t_0)
1.63 (0.4t_0) + 3-72 (0.5t_0)
Transmittance, %
100
80
70
60
50
40
30
20
10
0
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
Wavelength, mμ

Figure 3



SPECTRAL TRANSMITTANCE OF FILTER COMBINATION B
t_o Didymium (1-63) and t_o Noviol A (3-73)
$1\text{-}63t_o$
$3\text{-}73t_o$
$3\text{-}73t_o$
$1\text{-}63t_o$
$1\text{-}63t_o + 3\text{-}73t_o$
$1\text{-}63t_o + 3\text{-}73t_o$
Transmittance, %
100
80
70
60
50
40
30
20
10
0
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
760
Wavelength, mμ
NBS

Figure 4

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

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The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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